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Night airglow emissions at Calcutta

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Abstract : In this paper the night airglow intensity variations of 5577 Å, 5893 Å and 6300 Å line emissions at Calcutta are presented. Explanations for the variations of 5577 Å and 5893 Å lines are offered. The intensity variation of 6300 Å line is explained by Barbier ralation using *F*-region ionospheric parameters.

Keywords : Night airglow, intensity variation, *F*-region ionospheric parameters.

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1. Introduction

Lines and bands of night airglow emissions which depend among other parameters on locality have been measured by different investigators at various places of the world. The observations of total emission of certain spectral regions are given in Table 1. Again, the night airglow observations of OI 5577 Å, NaI 5893 Å, OI 6300 Å lines by different investigators are summarised in Tables 2, 3 and 4.

Taking advantage of the black-out condition of Calcutta during World War II, the total night airglow intensity was measured in 1946 by Ghosh by photographic method. In course of these observations, it was found that on certain nights, the variation of night airglow intensity follows the same trend as that of square of critical frequency of *F*-region (Mitra 1945, Ghosh 1946) (Figure 1). As the intensity of discrete airglow lines was not measured at Calcutta previously, it was decided to make observations of 5577 Å, 5893 Å and 6300 Å lines here using photoelectric method.

In experimental set-up Dunn-Manring type photometer was used. The experimental arrangements are shown in Figure 1 of previous paper (Ghosh and Midya 1986).

The filter characteristics for observing airglow emissions are given below :

Filter	Wavelength of peak emission (Å)	Half bandwidth (Å)
OI (Green line)	5577	80
OI (Red line)	6330	120
NaD (Yellow line)	5893	60

Table 1. Total intensity variation of different places.

Observer	Place of observation	Observed spectral range	Nature
Rayleigh (1929)	Terling, England	$\lambda < 5577$ Å	The intensity increases as night progresses, attains a maximum near about local mid-night and then begins to decrease.
Karandikar (1934)	Poona, India	Red, green blue and violet regions	The intensity decreases as night advances, attains a minimum near about local mid-night and then begins to rise again.
Cerniajev *et al* (1937)	Caucasus mountains	4550 – 5900 Å	Intensity increases as night progresses, attains peak intensity near about local mid-night and then begins to decrease.
Bradbury and Sumerlin (1940)	Mt. Hamilton, Central California	Yellow and green region	Obtained a maximum near about local mid-night. There is also an indication of a secondary maximum at about 3 a.m.
Barbier (1941)	Mt. Hamilton, Central California	Red and blue regions	For blue region, the variation is the same as that found by Rayleigh. For the red, there is a steady decrease throughout the night.
Elvey (1943)	McDonald Observatory, Taxas, U.S.A.	Total intensity	Obtained two types of observations : (a) same as that found by Karandikar, (b) slow and steady decrease in intensity throughout the night.
Ghosh (1986)	Calcutta, India	Total intensity	The intensity decreases with advance of night, attains a minimum near about local midnight and then rises.

The telescope was pointed towards west with the elevation angle of 45°W. Observations were taken at Ramakrishna Mission Residential College, Narendrapur (Lat. 22°35′ N, Long. 88°21′ E) about 18 km south of Calcutta. It may be noted

Table 2. Nocturnal intensity variation of 5577 Å line emission at different places.

Observer	Place of observation	Nature
Brenton and Silverman (1970)	Collected data from 22 places scattered throughout the world	The observations of all stations are not the same. It was concluded that the diurnal intensity variation pattern is not affected by solar cycle. The observations find no difference in the general pattern of the variation from solar minimum to maximum except that the absolute intensity is more during the sunspot maximum.
Tillu and Chiplonkar (1971)	Poona (19° N)	Observed two types of variations : (a) diurnal intensity variation curve shows the principal maximum in the pre-midnight period, (b) another type shows principal maximum in the post-midnight period.
Ciner and Smith (1973)	El Leancito (32° S)	No significant variation is observed. Intensity curves show weak minimum around midnight.
Singh and Chatterjee (1973)	Dumka (24° N)	Mean intensity remains constant throughout the night.
Rao and Kulkarni (1974)	Mt. Abu (24.6° N)	Intensity remains almost constant throughout the night. Some observations also show fluctuations during pre- and post-midnight period.
Ghosh and Kundu (1975)	Allahabad (25° 32′ N) (82° E)	Two maxima are observed. Early morning maximum is less pronounced than the first maximum around the local midnight.

that the OH bands are intense in the infrared region but not in the visible spectrum (Bertheir 1956). Hence the radiations recorded by the photometer are mainly due to the respective emission lines.

2. Observations

(A) 5893 A :

The intensity of 5893 Å line emission at Calcutta decreases exponentially from evening twilight and then remains constant throughout the night. No significant change in intensity was observed during the whole night. The intensity again rises exponentially during morning twilight (Figure 2). No observation differing from this general trend was observed.

(B) 5577 Å :

The observations of the intensity variation of 5577 Å line for four selected nights at Calcutta are shown in Figure 3. The intensity decreases exponentially from evening twilight values and in course of night exhibits two small maxima. The

Table 3. Nocturnal intensity variation of 5893 Å line emission at different places.

Observer	Place of ovserva-tion	Nature
Smith and Steiger (1968)	Tamanrasset (23° N) Haleakala (21° N)	No signaficant variation is observed. The intensity decreases during post-twilight period in the evening and remains constant almost for the whole night. It again increases during dawn twilight.
Saxena (1969)	Nainital (29.5 °N)	Observed a gradual decrease of intensity for the whole night.
Ciner and Smith (1973)	El Leancito (32° S)	Obtained similar observations as that found by Smith and Steiger (1968).
Weins and Weill (1973)	Tamanrasset (23° N) Zeekooegat (33° S) Haute Provence (44° N)	Intensity gradually decreases with the advance of night and almost remains constant for the whole night. It again increases during dawn twilight.
Weins and Weill (1973)	Adi Ugri (15° N)	The intensity decreases throughout the night after a small post-sunset rise.
Takahashi *et al* (1979)	Cochoeira Paulista (23° S, 45° W)	The intensity attains a minimum close to local-midnight. Between midnight and dawn, the intensity remains fairly constant or increases slightly. The most consistent feature is the pre-midnight decrease in intensity.

Table 4. Nocturnal intensity variation of 6300 Å line emission of different places.

Observed	Place of observa-tion	Nature
Smith and Owen (1966)	Haute Provence (44° N) Coctus peak (36° N) Tamanrasset (23° N)	The intensity decreases rapidly in the post-twilight hours in the early evening, attains a steady low value for the whole night. The intensity again increases in dawn.
Torr (1971)	Sanae (70° S)	Observed a large enhancement in the vicinity of midnight.
Walter and Steiger (1972)	Haleakala (20° N)	Observed predawn enhancement.
Rao and Kulkarni (1973)	Mt. Abu (23° N)	Enhancement sometimes is observed in the early part of the night and sometimes after midnight.
Salaria *et al* (1987)	Patiala (30° 30′N)	Two types of observations are obtained : (a) the intensity decreases first and remains almost constant for the rest of night, (b) the intensity shows nighttime enhancements which usually occur in the pre-midnight (2100-2200 hrs) or in the post-midnight (0300-0400 hrs) periods.

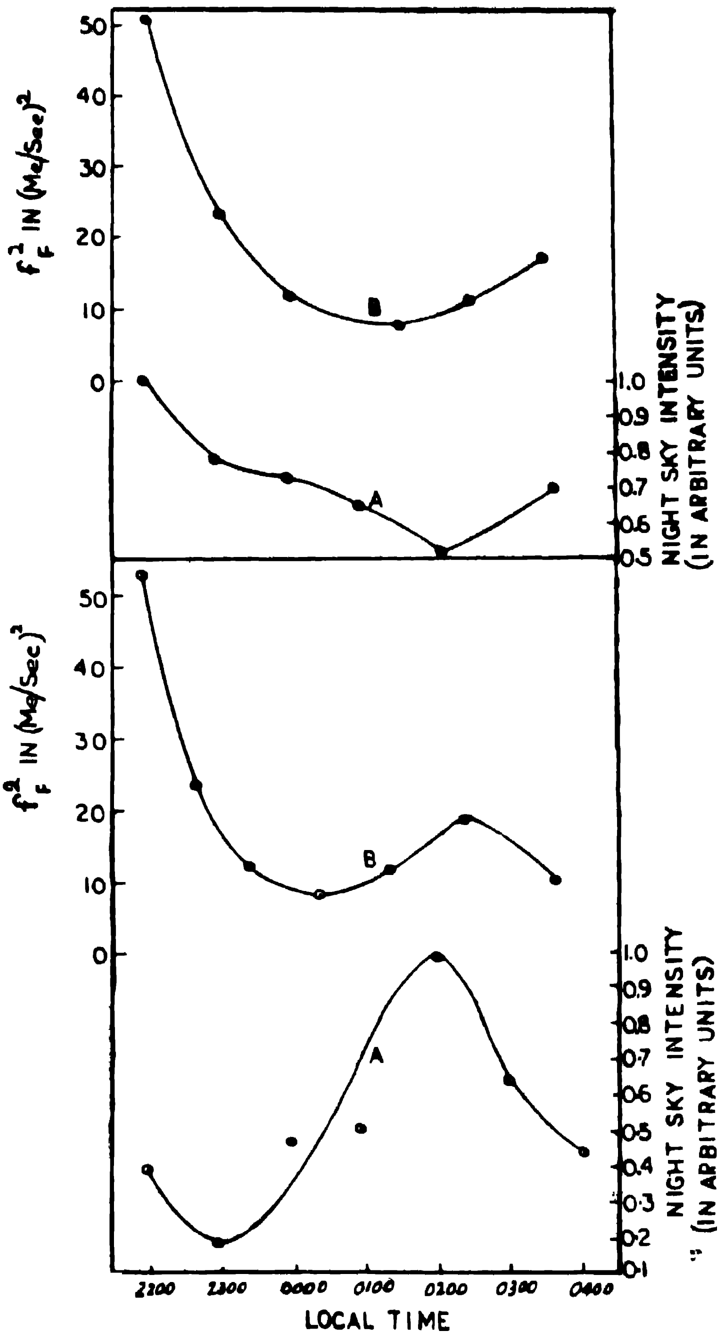

Figure 1. Comparison of the variations of the night sky intensity (A) with that of f_F^2 (B) for two abnormal nights with magnetic disturbances. The upper curves are for Feb. 14-15, 1945 and the lower curves for Feb. 15-16, 1945. It is to be noticed that the variation of the night sky intensity follows the same trend as that of f_F^2.

time of occurrence of maxima differs from night to night. One maximum is observed between 7-9 p.m. and the other around 2-4 a.m. Pre-midnight maxima are more pronounced than the post-midnight maxima.

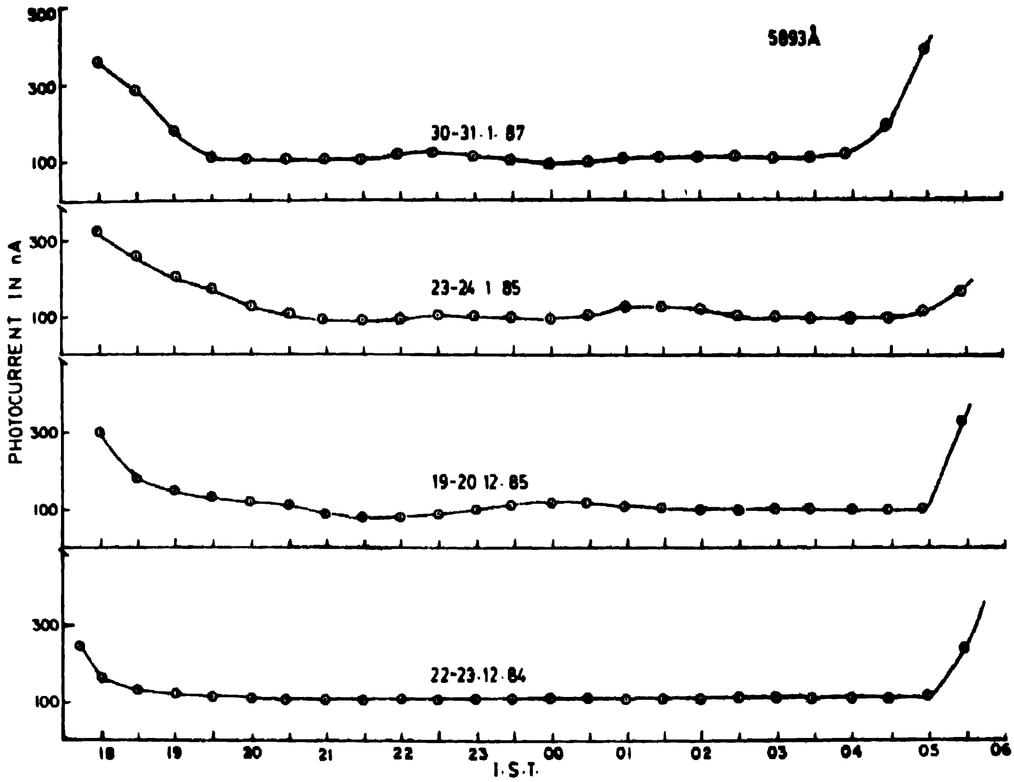

Figure 2. Intensity variation of 5893 Å line during night at Calcutta.

There are some abnormal nights (Figure 4). About 90% of observations follow the normal trend of variation as shown in Figure 3.

(C) 6300 Å :

The intensity of 6300 Å decreases sharply from the evening twilight to nighttime value. It begins to rise slowly after this post-twilight decay and attains peak value around 3-4 a.m. It again falls and then rises quickly and merges to dayglow value. A few observations are shown in Figure 5. There are some observations in which the maxima are not prominent (Figure 6). About 80% of observations follow the trend of variation as shown in Figure 5.

3. Discussion

It was shown that O_3 plays an important role for 5577 Å and 5893 Å twilight airglow emissions (Ghosh and Midya 1986). Also, the covariation of 5577 Å, 5893 Å and OH emissions are explained considering O_3 density variation (Ghosh and Midya 1987). Based on these considerations, the night time variations of 5577 Å and 5893 Å line emissions are explained as follows.

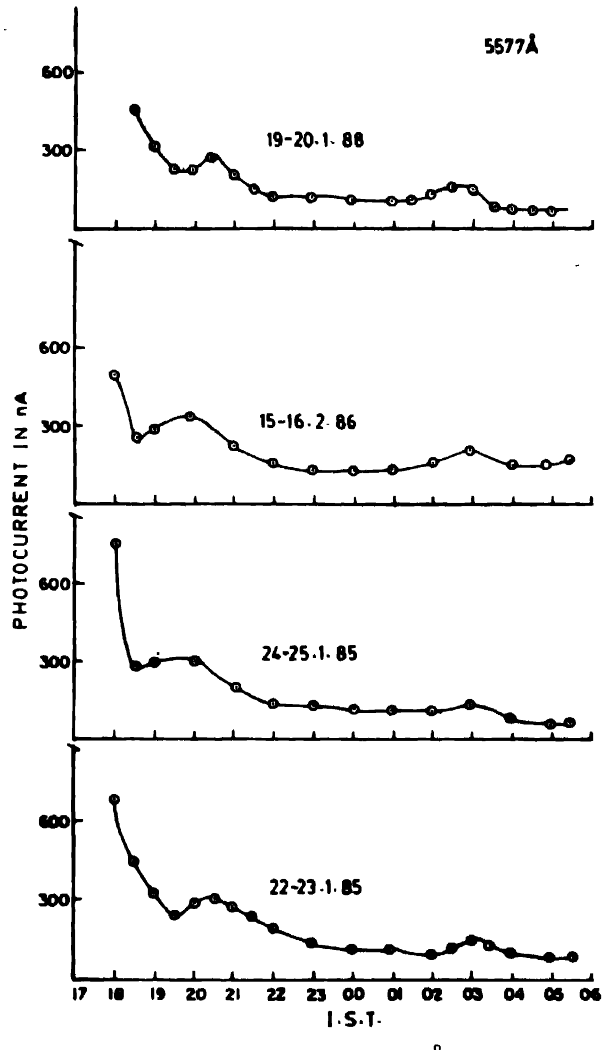

Figure 3. Intensity variation of 5577 Å line during night at Calcutta.

(A) 5893 Å emission :

Shimazaki and Laird (1972) showed that O_3 concentration above 85 km remains constant after a rapid post-sunset rise. The excitation mechanism of 5893 Å is given by

$$NaO^* + O \xrightarrow{k_1} Na^*(^2P) + O_2 \tag{1}$$

$$Na^*(^2P) \rightarrow Na\,(^2S) + h\nu\ (5893\ \text{Å}) \tag{2}$$

NaO* is produced by the following reactions

$$Na+O+M \xrightarrow{k_3} NaO^*+M \tag{3}$$

$$Na+O_2+M \xrightarrow{k_3} NaO_2+M \tag{4a}$$

$$NaO_2+O \xrightarrow{k_4} NaO^*+O_2 \tag{4b}$$

$$Na+O_3 \xrightarrow{k_5} NaO^*+O_2 \tag{5}$$

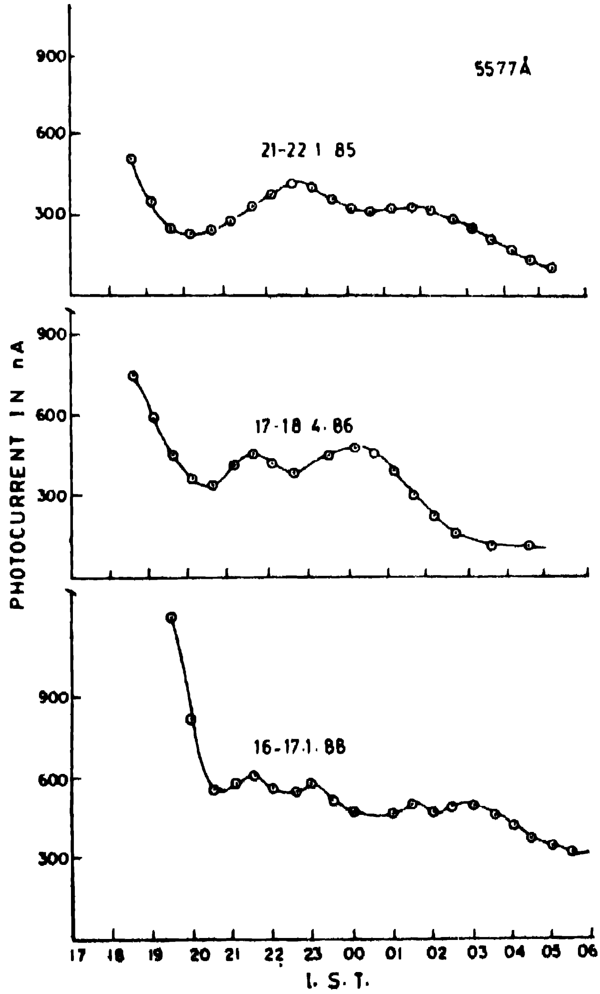

Figure 4. A few abnormal observations of 5577 Å line emission during night at Calcutta.

NaO* is mainly produced by reaction (5). As O_3 concentration remains constant throughout the night after a rapid post-sunset rise (Shimazaki and Laird 1972), it is likewise expected that the intensity of 5893 Å line during night should also remain constant.

(B) 5577 Å emission :

The excitation mechanism of oxygen is given by

$$O+O+O \rightarrow O_2+O(^1S)$$

$$O(^1S) \rightarrow O(^1D)+h\nu \ (5577 \text{ Å})$$

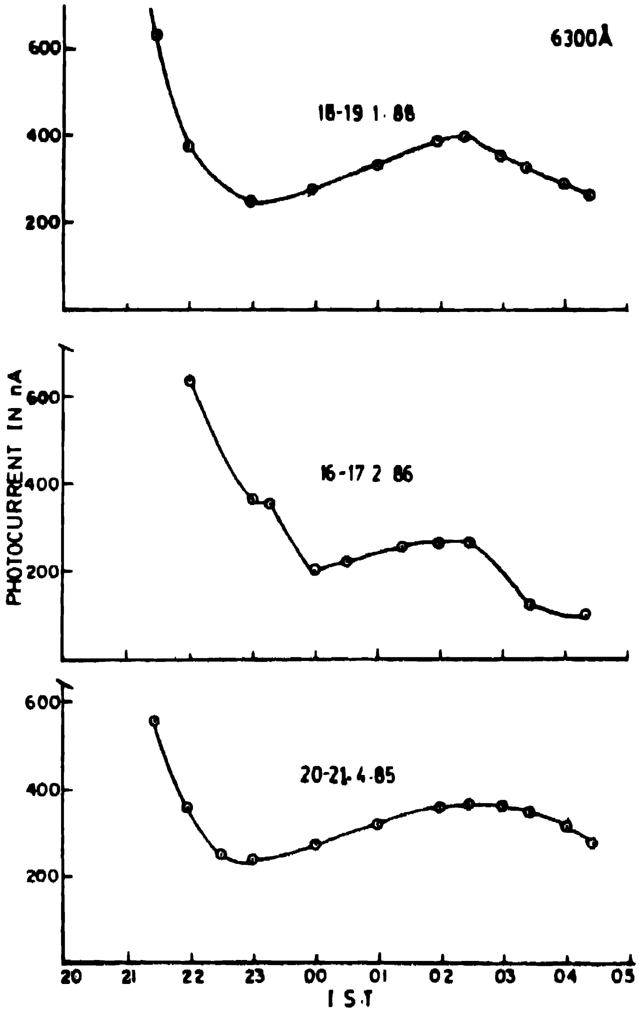

Figure 5. Intensity variation of 6300 Å during night at Calcutta.

Again, O_3 density is dependent on initial atomtic oxygen density. As O_3 concentration remains constant during night, the night airglow intensity of 5577 Å is expected to remain constant throughout night.

(C) 6300 Å emission :

It is well known that 6300 Å airglow radiation is excited by aeronomic reactions in the *F*-region of the ionosphere. Barbier (1959) proposed that the intensity of 6300 Å radiation can be calculated from ionospheric parameters of *F*-layer as follows :

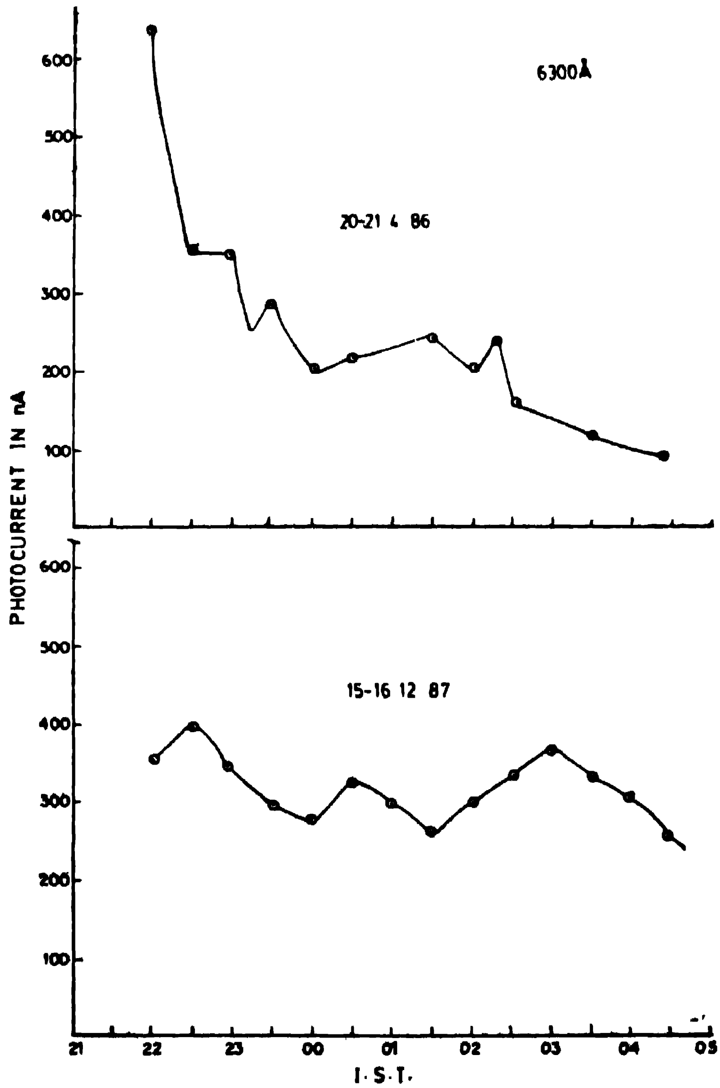

Figure 6. A few abnormal observations of 6300 Å line emission at Calcutta.

$$Q_{6300} = A + B(f_0)^2 \exp\left(-\frac{h'-200}{H}\right) \tag{6}$$

Q_{6300}—calculated intensity in R

A, B—constants of eq. (6)

f_0—critical frequency of F-layer in MHz

h'—virtual height of F-layer in km.

From eq. (6)

$$Q_{6300} - A = B \exp\left(\frac{200}{H}\right)(f_0)^2 \exp\left(-\frac{h'}{H}\right)$$

or,

$$Q'_{6300} = B'(f_0)^2 \exp\left(-\frac{h'}{H}\right)$$

$$\left[\text{where } Q'_{6300} = Q_{6300} - A \text{ and } B' = B \exp\left(\frac{200}{H}\right)\right]$$

or,

$$Q'_{6300} = B'\phi(f_0, h')$$

$$\therefore\ Q'_{6300} \propto \phi(f_0, h')$$

Since Q'_{6300} is obtained from Q_{6300} by subtracting a constant term A, the nature of Q_{6300} and Q'_{6300} curves should be the same. The diurnal variation of $\phi(f_0, h')$ is shown in Figure 7. The nature of variation of 6300 Å line intensity at Calcutta agrees fairly well with the variation of $\phi(f_0, h')$. The data from Calcutta ionsonde are adopted to calculate $\phi(f_0, h')$.

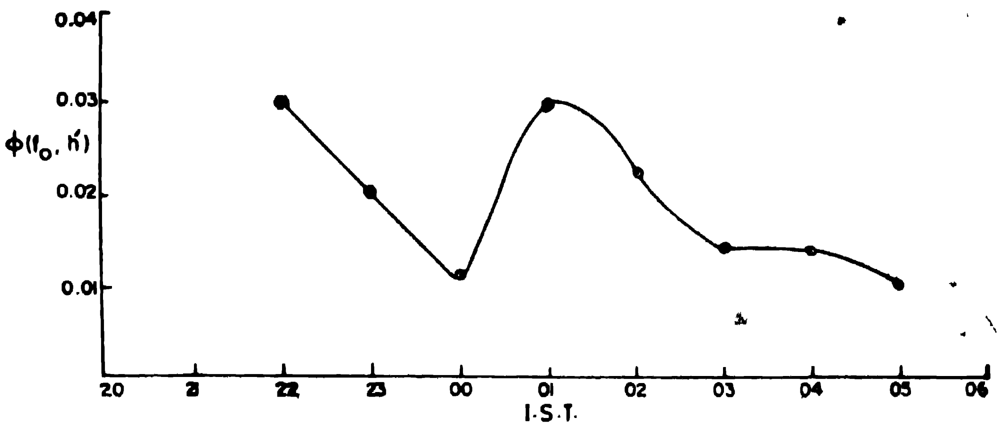

Figure 7. Diurnal variation of ϕ (f_0, h') at Calcutta.

It may be pointed out that previously different investigators (Rao and Kulkarni 1973, Salaria *et al* 1987) also showed that using Barbier relation intensity of 6300 Å line can be explained.

Fejer *et al* (1979) showed that the intensity variation of 6300 Å is consistent with the equatorial ionospheric vertical drift variation. Sahai *et al* (1988) concluded that these vertical plasma drifts are controlled by equatorial electric fields and produce similar type of variation of 6300 Å line intensity. Salaria *et al*

(1987) concluded that the post-midnight enhancement is due to the movement of the layer. The lowering of the layer increases the dissociative recombination of O_2^+ ions with electron (Ghosh and Midya 1989) and hence increases the yield of 6300 Å line intensity.

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